JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. V MARCH 19, 1915 No. 6

GEOLOGY.—*Some relations in origin between coal and petroleum.*[1]

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INTRODUCTION

It is my purpose this evening to present for your consideration some features of the problem of the origin of petroleum and natural gas. The plan followed is to view the question of the origin of petroleum from the standpoint of the origin of coal; to note how some of the fundamental conditions attending the formation of coal and its differentiation in kinds may similarly apply to oil; to call attention to some points both of difference and of agreement as to the paleontologic sources of these two great mineral fuels; and to inquire whether certain of their important characters, that are secondary in origin, are not conditioned by common causes.

At the outset it will be assumed that petroleum, as it occurs in a natural state in oil pools in most parts of the world, is the product of the geodynamic alteration of certain types of organic detritus buried in the strata of the outer shell of the earth; that, in other words, it was produced in accordance with the so-called organic theory. It will, however, not be denied that petroleum may be, and in fact has, in some cases, possibly been formed in accordance with the inorganic theory, which, in broad terms, is that petroleum is made chemically from substances of mineral

[1] Presidential address delivered before the Washington Academy of Sciences on January 14, 1915.

[2] Published by permission of the Director of the U. S. Geological Survey.

origin, as, for example, by the contact of percolating waters with deep-seated metallic carbides. The observations presently to be noted bear unfavorably on the theory of the inorganic origin of petroleum. The arguments both for and against all variants of the inorganic theory have been fully summarized by many geologists, both American and foreign,[3] and will not receive further attention in this paper, the aim of which is to throw additional light, from the geological standpoint, on the origin of petroleum.

THE INGREDIENT MATERIALS OF COALS AND OIL ROCKS

It is now almost universally agreed that coal of different kinds had its beginning as relatively pure deposits of more or less decomposed organic débris derived mainly from vascular plants. Coals of the common or humic types had their beginning as peats, mainly freshwater peats, those of the great coal fields having been, for the most part, laid down in great swamps or estuarine marshes.[4] The type of the coal—namely, whether it be xyloid, "amorphous," cannel, etc.—depends on the kinds of ingredient organic matter and on the conditions controlling the deposition of this matter. The common types are, to a great extent, composed of the remains of woody plants, portions of which are readily visible to the unaided eye. The more distinctly xyloid coals are largely made up of somewhat altered, but more or less readily recognizable wood, which may constitute more than 80 per cent[5] of the mass. Wherever the conditions of decomposition have been favorable for a more advanced disintegration of the débris through the action of micro-organisms, of which the most important are the bacteria, megascopic wood in the peat or coal is not so abundant; and where the

[3] See: Peckham, S. F., Tenth Census Report, **10**: 59. 1884; Orton, Edward, Geol. Surv. Kentucky, Report on the occurrence of petroleum, natural gas and asphalt rock in western Kentucky, p. 31. 1891; Haworth, Erasmus, Kansas Univ. Geol. Surv., **9**: 187. 1908; Engler, C., and Höfer, Hans v., Das Erdöl, **2**: 59. 1909; Clarke, F. W., U. S. Geol. Surv., Bull. **491**: 693. 1911; Höfer, Hans, Das Erdöl und seine Verwandten, p. 214, 1912; Redwood, Boverton, Petroleum, 3rd ed., **1**: 268. 1913.

[4] White, D., Bur. of Mines, Bull. **38**: 62. 1913.

[5] Thiessen, R., Loc. cit., p. 221. 1913.

microbian action has progressed further the coal-forming substance consists more fully of the products of the biochemical decomposition of the vegetal matter, in which the surviving, often comminuted, structural fragments, consisting of the tissues and plant products most resistant to the agencies of subaqueous decay, are embedded. Coals originating in mature or much decomposed peats and containing little coarse detritus are sometimes called "amorphous," although they are never without vestiges of plant structures.

In many cases the decay of great amounts of resin-bearing gymnospermous wood has, through the disintegration of the woody tissue, set free and effected a concentration of large quantities of resinous matter which was resistant to the decomposing agents in the peat swamps or bogs. Also, under certain conditions of deposition, especially where the water was too deep for the growth of subaerial types of vegetation, and stagnant or nearly so, the organic mass may have been largely or almost wholly made up of the spore and pollen exines and grains of resin, mingled in varying proportions with aquatic plant and animal life of low orders, some of which is plankton. The latter may include the remains of innumerable algæ, with protozoans, small crustacea, insect eggs and larvæ, small gastropods, etc., and even fish. More or less spore, pollen, and resin ingredients enter into the xyloid and other coals of the ordinary types; but whenever they become conspicuous in the composition of the coal, they impart a so-called "fatty" quality to it; and when they form the greater part of it, being generally mingled with increased amounts of plankton material, as is natural in an open water habitat, they form cannels.

Between coals of the ordinary, or humic, types and the cannels there is complete intergradation. Locally, according to the circumstances of deposition, the Paleozoic cannel coals contain peculiar forms of organic remains that have, by most paleobotanists, been regarded as algæ of very low groups.[6] If the so-called algæ and other plankton remains predominate, composing the greater part of the organic deposit, the latter is called

[6] Renault, B., Microorganismes des combustibles fossiles, p. 151. 1893.

a *boghead* or an *oil rock;* although if the rock is sufficiently low in mineral sediments, it is in reality a type of cannel. On the other hand, if mineral sediments are mingled in quantities too high to admit the classification of the rock as a coal, it is known as an *oil shale,* or a *bituminous* shale. Lesser amounts of such organic matter ordinarily gain recognition only as rendering the shale "carbonaceous." Deposits of decaying spore and pollen material, with both vegetal and animal débris, laid down as organic oozes, slimes or muds, were designated by Potonié as "sapropel."[7]

Coals, including cannels, and oil shales from many regions and geologic formations have been examined in detail under the high-power microscope, and the organic detrital remains which compose and characterize the several types have been splendidly, sometimes even elaborately, demonstrated by paleontologists[8] both in Europe and America, though the botanical or zoological classification of the fossil remains composing the deposits may, in many cases, be subject to question. However, for our present purpose, it is important only to note some of the qualities or characteristics which certain among the different kinds of organic débris impart to the deposits which contain them.

The woody matter which forms the large part, at least, of the ingredient substance of ordinary peats and their alteration products, xyloid coals, laminated coals, etc., is largely composed of cellulose, lignose, xylose, etc., comprising carbohydrates relatively high in oxygen. These ordinary coals, including those commonly (though really inappropriately) called "bituminous," are therefore, as will be seen, characteristically high in oxygen. They are, accordingly, characteristically rich in so-called humic acid compounds. Hence, they have very properly been designated[9] as humic coals. On the other hand, the decay-resistant elements, such as spore and pollen exines, seed envelopes and

[7] Potonié, H., Die Entstehung der Steinkohle, 5th Ed., p. 3. 1910.

[8] Renault, B., Microorganismes des combustibles fossiles, 1893; Bertrand, C. Eg., Les charbons humiques et les charbons de purins, 1898; Potonié, H., Die Entstehung der Steinkohle, 1910; Stopes, M. C., and Watson, D. M. S., Phil. Trans. Roy. Soc. London, Ser. B., **200**: 167. 1909; Thiessen, R., Bur. of Mines Bull. **38**, 1913; Jeffrey, E. C., Economic Geology, **9**: 730. 1914.

[9] Potonié, H., Die Entstehung der Steinkohle, p. 95. 1910.

certain cuticles, are generally provided with resinous, waxy or oily protective substances. These, as well as the resin grains with which they are in most cases mingled, are all characteristically very high in hydrogen and low in oxygen. Thus it happens that the rocks in which they are prominent are from the start, as initial organic muds, more distinctly bituminous in composition. As the fossil remains last named, mingled with other fat-, oil- and albuminoid-producing animal and plant ingredients, predominate more and more, the contrast with the ordinary—the humic—coals, becomes still stronger, the most marked contrast being found in the so-called algal deposits, which characterize many of the typical "*oil shales.*" Further, as the high-hydrogen ingredients become prominent or predominate the fuel in general becomes richer in volatile matter and higher in calorific value. Finally, it is to be noted: First, that these deposits compose or characterize the oil rock series, as has been pointed out by Renault, Bertrand, Potonié and others; and second, that in succession the cannels, boghead cannels, cannel bogheads and bogheads appear to yield, on artificial distillation, larger proportions of petroleum. A Reinschia boghead, the so-called kerosene shale of New South Wales, is said to run as high as 87 per cent in volatile hydrocarbons.

Deposits containing in large proportions such organic detritus, characteristically high in hydrogen and low in oxygen, are typical mother rocks of petroleum. As the proportions of waxes, exines and resins become greater in the deposit, the distillates, obtained by the artificial distillation of the fuel, approach in characters more nearly to the natural petroleums; and when they constitute the greater part of the organic detritus, as in the cannels, or when, finally, the material is more distinctly "sapropelic," containing great numbers of, or even composed almost wholly of the so-called algæ, the artificial distillates are, in general, not only much greater in volume, as is to be expected on account of the composition of the original débris, but they form petroleums of higher ranks. It would appear that, other things being equal, the maximum yield of oils of high quality is obtained from the supposed alga coals or bogheads.

Organic remains of the spore or sapropelic type are found in every bituminous shale or so-called oil rock that has yet been examined. It is to the presence of such carbonaceous débris, embracing sapropelic matter, all more or less disintegrated and decomposed, that, in most cases, are due the dark tints of shales, sandstones and limestones. The sufficiency of such matter to produce the petroleum taken from the oil fields has been well demonstrated. In this connection, it will be recalled that, prior to boring for underground oil in Pennsylvania, about 1848, oil shales in several geological formations were distilled to obtain the petroleum supplies of this country. Shales are now being distilled for oil in Scotland and France.

In this discussion, the terms *oil rock* and *oil shale* are applied only to those rocks that yield petroleums when the organic matter deposited in them as sediments is decomposed by destructive distillation. The terms do not apply to sandstones, porous limestones, or other rocks, in which petroleum is merely occluded or held in the interstices of the grains of mineral matter.

To what extent the characters of the distillates obtained by any given method from the different coals, cannels, bituminous shales, and other oil rocks are due to differences in the composition of the original ingredient organic matter of the deposits is not known. For my own part, I am inclined to attribute to this factor certain differences in the characters of natural petroleums, such for example, as high sulphur or high nitrogen content, richness in asphalt or brownness, rather than any great differences in the rank or grade of the oils. More probably the principal differences in the actual rank of petroleums are, in general, due to physical causes, as will later be indicated.

TWO PROCESSES IN THE ALTERATION OF THE ORGANIC DETRITUS.

The Biochemical Process

In the foregoing summary we have considered only those differences in the types of coal and other sedimentary organic desposits that were determined at the initial stage, that is, at the time of the deposition of the vegetal and animal débris. These differences between the types of detrital hydrocarbon

deposits, humic coals, cannel, boghead, etc., are, as has been indicated, dependent upon (1) the kinds of original contributary, organic material, their chemical compounds and the varying proportions of the latter; and (2) the character and extent of the microbian action, whose work depends, both as to extent and as to character, on the kinds of host detritus and the conditions of deposition. The latter embrace all environmental factors, such as temperature, moisture, access of air, concentration of toxic biochemical products, etc., and flushing by water drainage, on which, to some extent, rests the conservation of the varied biochemical decomposition products, especially those that are liquid or that enter into aqueous solution. All this concerns merely the accumulation and more or less complete decomposition of the organic débris in the form of peat, organic muds, calcareous oozes and so forth. As soon as the organic débris is buried and the oxygen so far exhausted that bacterial action is no longer possible, or when toxicity puts an end to all micro-organic action in the deposit, there comes the end to this, the first stage in the formation of coal. This is the *biochemical stage* of coal formation. The exact point at which the biochemical process terminates has not been accurately observed in any single case, but it appears to correspond approximately to the burial of the peat and the complete smothering of the organic matter in the mud, beneath superposed deposits.

A fact which is most important is that, complicated and indispensable as is this biochemical process, it appears to carry the organic deposits little or no farther than the formation of peats and organic muds, buried oozes, etc.

The Dynamo-chemical Process

Leaving now the work of the biochemical process in the formation of coals and other carbonaceous sedimentary deposits, we pass to the consideration of the *alteration* of these deposits to coals and hydrocarbon rocks of higher ranks, as a result of geo-dynamic action. We have now to do with the changes in the physical and chemical characters of the organic matter, accomplished through the dynamo-chemical process or the second stage in coal formation.

This process covers the compression, the gradual dehydration, lithification and induration of carbonaceous rocks, including the coals; the development of cleavage and even schistosity in the deposits; and, simultaneously and progressively, the elimination of the combined oxygen, the hydrogen, the nitrogen, and a part of the carbon of the organic débris. By this process the peats are gradually transformed to lignites, sub-bituminous coals, bituminous coals, semi-bituminous coals, anthracites, and even to graphites, while the associated organic muds are altered to oil rocks or cannels, to carbonaceous shales, and finally to graphites or graphitic slates. This alteration and reduction of the carbonaceous deposits is most clearly marked by the progress of the elimination of the "volatile matter."

The changes both in the physical features and in the chemical composition of the deposit, as it is transformed from peat to graphite, constitute in effect a metamorphism of the organic matter.[10] The extent of the transformation, that is, its progress, varies with the extent of the dynamo-chemical action.

The study of the coals, in many coal fields, and of different ages, shows that the alteration may be produced in two ways. The first is through distillation, by local heat incidental to contact with sills, dikes or flows of molten rock. Such contact metamorphism, though frequent and conspicuous, is so closely confined to the near vicinity of the igneous intrusives, that its effects, from a regional standpoint, are practically negligible.[11] The other dynamic cause of the alteration of the organic débris is pressure.

The study of the stages in the alteration of the coal in different regions shows, in general, a close relation between the extent to which the rocks have been subjected to thrust pressure metamorphism and the degree to which the mother peats and sapro-

[10] The chemical combinations actually existing in coals and petroleums of different ranks and types are largely unknown. Portions of the coal leached by reagents and extractions or separations from petroleums have been chemically identified, and products resulting from destructive distillation of both the solid and the liquid fuels have been determined; but most of these probably are compounds obtained by breaking up the largely undetermined original chemical combinations.

[11] Bureau of Mines, Bull. **38**: 101. 1913.

pelic deposits have been altered. This relation has long been recognized and is known to be regional in effect, though the extent of the dynamic influences and the differences in the dynamo-chemical results vary from one point to another within the region. Coal appears to be more responsive to pressure than are the environing strata. Its sensitiveness to dynamic action makes it possible, through the changes in the fuel, to recognize this action in regions where other indications are obscure and difficult to detect.[12]

The explanation of the dynamic alteration of coals as the result of thrust was long ago proposed and has been accepted by most geologists, especially in America, though it has gained fewer adherents in Europe, where the coal fields are smaller and the strata of most of the basins containing higher rank coals are folded and faulted. Anomalous variations in the carbonization of the coals in folded and particularly in faulted strata, and the presence of coal high in volatile matter near faults, all of which at first seemed fatally opposed to thrust metamorphism as a hypothesis, have, on the contrary, been shown to constitute essential proof of the validity of the theory. In another place[13] I have shown that abnormally high percentages of volatile matter sometimes found in coals lying in folds, and generally to be observed near thrust-faults in coal fields, are really due to compensation or neutralization of the thrust by buckling of the beds and by the faults themselves. Through the shortening of the crustal arc by folding or by over-thrust of broken beds the stress is partially compensated and the coals are enabled to escape the maximum pressure intensity. In the regions of great coal alteration, the shortening by mere horizontal compression, which gradually takes up the stress and diminishes the pressure delivered at the far side of the arc, must have been very considerable.

It is probable that, except in cases approaching graphitization, the temperatures of coal alteration were never so high as those necessary to accomplish the earliest effects of metamorphism generally recognized by geologists in other rocks; yet the

[12] U. S. Geol. Survey, Bull. **150**: 142–145. 1898.
[13] Bureau of Mines, Bull. **38**: 114–125. 1913.

friction heat of molecular displacement caused by the stresses of intermittent thrusts of progressive intensity was generated throughout such an enormous thickness of rocks and through so great an area as to produce sensible temperatures under conditions necessitating long periods for their dissipation.

The effectiveness of thrust pressure as the cause of regional coal alteration is well illustrated in most large areas of high rank coal, but in no part of the world is it more clearly demonstrated than in the great Appalachian coal field. To show in a general way the progress of the regional alteration in this area, I have, in preparing the accompanying map, first platted the "fixed carbon" (pure coal basis) of the coals at the localities from which samples have been analyzed.[14] Lines were then drawn through the points of equal fixed carbon (or volatile matter). Such lines, which were termed "isoanthracitic" lines by Strahan[15] and Pollard, and which I have termed "isovols," are drawn to mark each 5 per cent of increase in the fixed carbon in the pure coal. The degree of accuracy of the representation will not here be discussed. The "contouring" of the fixed carbons is subject to minor revision.

A glance at the Appalachian coal field in this map shows the position of the lowest rank coals to be in the western portion of the area, while the highest rank coals, the anthracites, are found at the extreme eastern border. The isovols show both the extent of the alteration of the coals and the regional progressive character of that alteration toward the Atlantic; that is, in the direction from which the great isostatic Appalachian thrusts are known to have come. Small areas of coal with slightly higher fixed carbon indicate, in most cases, points of locally greater, perhaps of cumulative, stresses, while "islands" of low fixed carbon probably mark areas of corresponding partial immunity. The more important thrust faults, lying within or

[14] The use of the fixed carbons, though less satisfactory on the whole than the C-O ratios of the dry coals, makes it possible to employ the great volume of proximate analyses illustrating coals in far greater geographical extent and completeness of representation. In the regions of lower rank coals, it is necessary to use some other method to show satisfactorily the rank of the fuels.

[15] The Coals of South Wales Coal Field, p. 72.

along the border of the coal field, are also shown on the map. The character of the folding of the valley regions and the faulting to the eastward is shown in the folios of the Geologic Atlas of the United States and in the State geological maps.

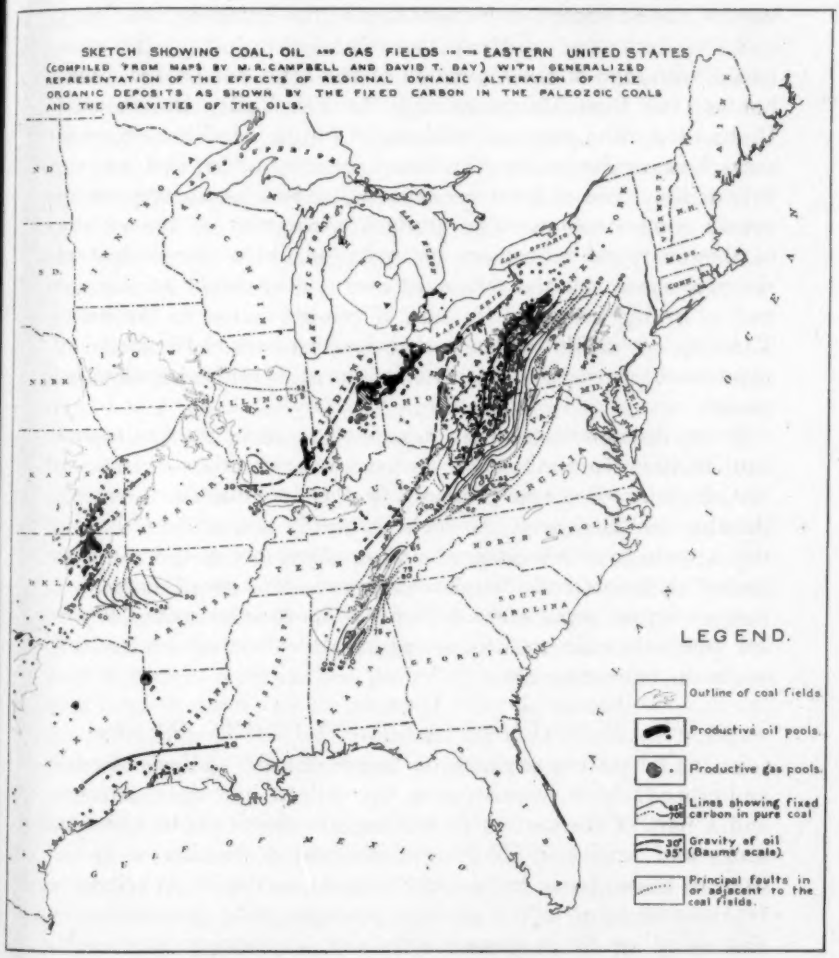
SKETCH SHOWING COAL, OIL AND GAS FIELDS IN EASTERN UNITED STATES
(COMPILED FROM MAPS BY M. R. CAMPBELL AND DAVID T. DAY) WITH GENERALIZED REPRESENTATION OF THE EFFECTS OF REGIONAL DYNAMIC ALTERATION OF THE ORGANIC DEPOSITS AS SHOWN BY THE FIXED CARBON IN THE PALEOZOIC COALS AND THE GRAVITIES OF THE OILS.
LEGEND.
Outline of coal fields.
Productive oil pools.
Productive gas pools.
Lines showing fixed carbon in pure coal
Gravity of oil (Baumé scale).
Principal faults in or adjacent to the coal fields.
GULF OF MEXICO

Fig. 1. Regional alteration of coals and petroleums in Eastern United States.

Without going further, at this time, into details as to the effects of folding and faulting in neutralizing the dynamic stresses, attention is called to (a) the larger volatile content in those parts of the anthracite fields that extend into the region of closer folding; (b) the anomalous variations seen in the Broadtop, the Coosa and Cahaba basins which lie in fault blocks; and (c) the relatively low stage of the alteration of the coals behind the Pocahontas, the Pine Mountain and the Elk Valley overthrusts. Undoubtedly the greatest intensity of initial stress has, in most cases, been exerted where the strata are most folded and broken. Where the stresses have been equal, it has been competency versus compensation. The gradual absorption of the energy of the westward movement by compression in the horizontal series is shown by the westward decrease of minor folding, as well as by the westward increase of volatile matter in the coals. There is no visible evidence that igneous rock metamorphism has caused any regional alteration of the coals in the Appalachian trough.

In the districts where high rank coals occur in the Cretaceous and Tertiary formations of western America, the evidence of the efficiency of thrust pressure, as the dynamic force causing the chemical change of the coals, is hardly less evident than in the Appalachian province, the phenomena being the same as in the Paleozoic areas, though the ranges in rank are often greater. In the western regions, the influence of igneous intrusives, which are relatively numerous, is conspicuously restricted and ineffective in the regional sense.

THE "DEVOLATILIZATION" OF THE ORGANIC DÉBRIS

In the laboratory methods of "approximate" analysis of coals and other carbonaceous deposits, the oxygen, hydrogen, nitrogen and a part of the carbon of the organic débris are distilled by a dry and semi-open air process, the matter, eliminated in the form of gases, being known as "volatile matter." It seems to be assumed that, in the geologic processes also, the substances eliminated are all in gaseous form and, accordingly the results are frequently described as the "devolatilization" of the organic

deposits. Nevertheless, when it is remembered that the organic compounds actually present in coals and bituminous shales are largely undetermined; that the conditions of geologic distillation are fundamentally different from those provided in the laboratory, and that the residues obtained at all stages in the laboratory process are widely different from those found in the earth, doubt is cast not only on the assumed similarity in the states and chemical composition of the eliminated matter but also as to whether all the matter is expelled as gases. Furthermore, it is probable that the natural distillates, generated under different geological conditions (from organic matter which itself may vary widely in chemical composition), vary both as to their chemical compounds and as to their properties far more widely than do the artificial distillates obtained from the same organic deposits.

Attention has already been given to the differences between the high-oxygen ingredient matter of the typical humic deposits (coals) and the high-hydrogen ingredient material of the typical cannels and oil rocks. Obviously, the volatile matter expelled from the former contains larger amounts of oxygen in some one or more combinations, while the volatile matter from the latter is rich in hydrogen. The reduction of these organic deposits, which intergrade one with another, will be discussed more fully in a later report. The two most important facts to be noted in passing are, first, that coals and oil rocks have yielded "volatile matter" products in different proportions and probably in very different compositions and structures also; and, second, that in both cases the processes of "devolatilization" result in the reduction of the solid residues through chemical changes that accomplish, in effect, their carbonization.

REGIONAL ALTERATION OF ORGANIC DÉBRIS AND CORRESPONDING REGIONAL DIFFERENCES IN PETROLEUMS

Having briefly reviewed some of the effects of regional dynamic influences, principally thrust pressure, in the progressive alteration of the carbonaceous residues, represented by coals, oil rocks, carbonaceous shales, etc., we will next inquire whether

the liquid distillates, the petroleums, found in different regions reveal any differences corresponding to the stages in the regional alteration of the carbonaceous residues.

In entering on the observations necessary to the comparison of petroleums from regions of varying degrees of alteration of the organic detrital deposits, many difficulties are encountered: There is no adequate volume of chemical analyses of petroleums from different oil fields and geologic formations. On the other hand, we find fractionation, lacking as to uniformity of method, and often made from deteriorated or unreliable samples, for commercial information. In comparatively few cases is the proportion of any single hydrocarbon determined. The only data obtained by approximately standardized methods and covering samples of geographic and geologic range, sufficient for comprehensive inter-regional comparisons, consist of specific gravity determinations. These, though they are the best criteria at hand, are also far from satisfactory, for, while in general the oils of lightest gravity are of the highest rank, containing the largest amounts of light (saturated) hydrocarbons, with largest proportions of hydrogen, and of lightest density, the gravity records can not take the place of chemical determinations of the hydrocarbon compounds in the study of the genetic features and the chemical classification of the petroleums. Furthermore, the gravity records contain unknown errors, due to the conditions of the samples as well as to the sources of the latter. Many of them represent shallow sand oils, from which the lighter elements have escaped up the dip or to the surface; which have stood in tanks or in wells intermittently pumped; which are affected by meteoric waters; or which were taken from mere seeps, shafts or springs. On the whole, however, the gravities of representative samples approximately show the rank of the petroleums and may, therefore, be utilized in a rough comparison of the oils from different regions. In view of the present lack of standardized analytic or fractionative criteria in sufficient abundance from both the stratigraphic and geographic standpoints for detailed studies, the conclusions which I have to offer are to be regarded as a report of progress.

Conforming to the prevailing usage in this country, I have, in the following discussion, used the Baumé system, in which the increase in the number of degrees is inverse to the increase in gravity.

In most petroliferous regions of the world the oil pools lie in or near (often beneath) formations carrying coals. Accordingly, it is generally possible to learn the stage of the regional metamorphism, approximately at least, by the extent of the alteration of the coals where, as in most cases, analyses of the carbonaceous shales in the oil-bearing strata are lacking. The geographic relations of petroleum pools to the coal fields will be at once seen if David T. Day's oil map of the United States, recently published by the U. S. Geological Survey, be compared with M. R. Campbell's coal map, published in Mineral Resources for 1910. (See also Coal Resources of the World, Ottawa, 1914.)

OCCURRENCES OF HIGHER RANK OILS IN REGIONS OF GREATER ALTERATION OF CARBONACEOUS RESIDUES

Is there any relation between the rank of the oils of any region and the degree of the alteration of the carbonaceous matter of the organic débris in the oil-bearing or in the overlying formations? Do the petroleums show regional differences of rank corresponding to or comparable with the differences in the rank of the coals in the various provinces? Unsatisfactory as the criteria employed in the comparisons may be, the answer to these questions is not only affirmative but it is conclusively so. A review of the data reported from the various oil fields of the world leaves no room for doubt on this question.

If we examine the oils of the United States, we find that in those formations and regions in which the carbonaceous detrital deposits (coals) are but little altered by dynamic influence, the oils are heavy and of low rank; that is, they are of high gravity. On the other hand, in regions of more advanced alteration of the residual organic débris, the oils are in general of correspondingly higher ranks (lower gravities), the highest degree of alteration of the residues being, in general, noted in the regions of highest rank oil pools.

In the Coastal Plain regions of Texas and Louisiana, where the coals of the Tertiary formations have not passed the stage of brown lignites, the oils of the associated beds are low in rank, with gravities falling, in most cases, between 17° and 24°, though tests of samples from certain localities are reported to show a gravity as low as 33° Baumé. The Tertiary oils in California are, on the whole, similar in gravity range. Some notable fluctuations in the oils of this State are apparently to be accounted for as due to deteriorated samples, to losses through porous covering strata, to local dynamic action, etc. A number of samples of oils of exceptionally low gravity from this State, as well as from the Olympic region of Washington, may owe their peculiarities to filtration or to greater local alteration of the rocks in folded districts. These exceptions affect but slightly the general average of the pools or fields. The Cretaceous rocks in northern California, in which the alteration of the carbonaceous deposits is more advanced, appear to contain oils of distinctly higher rank, corresponding to the oils in sub-bituminous areas or in regions of low rank bituminous coals. In the Coalinga field, the middle Tertiary oils, many of which may have probably suffered losses, average between 18° and 20° Baumé, but a gravity of 34° is reported for the oil in the Cretaceous underlying the anticline at Oil City, at the northern border of this field. Similarly, the oils in the Texas Cretaceous, which carries subbituminous coals, range from 32° to 39° in gravity; the still higher grade oils, ranging from 39° to 43° in gravity, in the Caddo field of Louisiana, are found in sands near the base of the Upper Cretaceous.[16]

In Wyoming the evidence is somewhat conflicting, apparently on account of the nature of the samples tested, many of these having been taken from springs or from wells of so light production or of so shallow a depth as to be subject to the effects of either evaporation or contamination. It appears, however, that the oils from rocks of the lignitic stage of alteration in this State average about 22° to 24° in gravity, while the oils from

[16] Caddo Lake is probably over the westward trending Appalachian coal measures and may possibly have derived its oils from the latter.

Cretaceous beds, associated with or underlying sub-bituminous coals, show gravities averaging about 35° or 36°. In the Evanston region, where the oils range from 38° to 43°, the coals of the overlying formation are reported to be of high sub-bituminous rank.

In Utah and Colorado, the oils of the Green River formation, in which the carbonaceous deposits have not passed the lignitic stage, are of low rank, having gravities of 26° or less; but the oils found in the Rangeley field, in Cretaceous strata beneath rocks containing medium rank bituminous coal in the same basin, show a gravity of 43° which corresponds to the stage of the alteration of the coals. In the Florence oil field in Colorado, oils averaging 30° or 31° are found in shales underlying coals of very low bituminous rank. Oil of 39° gravity in the Boulder coal field is said to occur in the Pierre shale at depths of more than 2000 feet below the base of the Laramie of the region, in which the coals, of high sub-bituminous rank at Marshall, appear to be progressing in alteration westward toward the oil field.

The broad area of almost undisturbed upper Paleozoic strata in the Mississippi Valley and middle States offers an unrivalled field for the study of petroleum with reference to the regional alteration of the carbonaceous deposits. In eastern Kansas the oils, which occur in Pennsylvanian strata carrying coals of very low bituminous rank, range, for the most part, from 32° to 34° in gravity, though in passing southward to the Oklahoma line and onward through the Osage Nation and beyond the Glenn pool, the oils show an increase in average gravity;[17] those in the Osage region ranging, in general, from 33° to 36°. Farther southeastward the gravities rise to 39° or 40° at the edge of the developed field.

The Madill oil, found in the basal sands of the Cretaceous, undoubtedly owes its low gravity, 47°, to its source in the immediately underlying Pennsylvanian strata, which are tilted and compressed in the Arbuckle uplift.

In the coal fields of Illinois and Indiana, where the coals are of low bituminous rank, but somewhat better than those of

[17] See R. H. Wood, U. S. Geol. Survey, Bull. **513**: 36. 1913.

eastern Kansas, the oils in the Pennsylvanian rocks appear to range from 29° to 39° Baumé, averaging about 31° to 34° in gravity. In this field there appears to be slight evidence of betterment of the rank of the oil in passing southward, as is to be expected in view of the southward improvement in the rank of the coals, though the data examined are not really sufficient.

It is interesting to note that the oils of the "Trenton" in eastern Indiana and northwestern Ohio, as well as those in the Silurian and Devonian of eastern Michigan and western Canada, though of gravities to be expected in regions where the nearest coals in younger formations are of bituminous rank, are not of so high rank as the oils in Carboniferous rocks in the regions of greater alteration nearer the eastern border of the Appalachian oil fields. This circumstance I believe to be due to the diminution of the intensity of the post-Paleozoic thrusts in this region, while the rocks of Trenton age and other pre-Carboniferous formations have not been subjected to dynamic stresses so vigorous as those endured by the Carboniferous rocks in West Virginia and western Pennsylvania. It is, however, to be noted that the "Trenton" oils are of higher gravity than the Carboniferous oils in the bituminous coal regions of Indiana and Illinois and it is almost certain that they are of higher rank than would be found in overlying Pennsylvanian rocks were the latter present in the "Trenton" region. It is also seen that the oils of the "Clinton" sand districts of Ohio are but slightly better in gravity than those of the Carboniferous nearest on the east.

In the great Appalachian oil field, the petroleums found in the Carboniferous sands range, in general, from gravities of 38° to 44° on the western, to gravities of 46° to 48° Baumé on the eastern margin of the productive field. The best oils, showing gravities of 49° and 50° or even 52° are found along or near the eastern margin of the field, in northern West Virginia, western Pennsylvania and western New York.[18]

[18] The gravities of the oils in this region vary somewhat from point to point and from sand to sand, the rank of an oil in a Devonian sand being locally inferior to that in the overlying Carboniferous, though, in general, it appears that, even in this region, the sands in the older or underlying formations contain oils of highest rank.

It is thus seen not only that the oils found in the regions of higher alteration of the carbonaceous deposits are in general higher in rank than are those in regions of lesser alteration, but also that in a single region the rank of the oil increases, *pari passu*, in the same direction as does the alteration of the carbonaceous deposits. This is clear when reference is made to the progressive alteration of the coals in passing eastward through this region, as is indicated on the map. Doubtless some of the local fluctuations are due to local variations in the intensities of the dynamic stresses. Others may be due to unknown circumstances connected with the sampling, to variations due to filtration, or to differences in the composition of the organic débris in the mother rock.

A further examination of the map for the purpose of comparing the trend of the eastern border of the productive oil region with the trend of the isovols (isoanthracitic lines) which have already been described, shows a degree of parallelism which is all the more surprising when it is known that the "contouring" of the fixed carbons of the Coals was done long before the inspection of the oil maps suggested a close comparison. It is seen that, in general, the eastern border of the oil field falls near the 60 per cent fixed carbon line, though small pools appear to have been found near the 65 per cent line. Gas pools fringe the oil field in a zone of higher alteration, but no pool of commercial size appears to have been found anywhere in the Appalachian trough so far east as the 70 per cent line. In fact, it appears probable that a revision of the isovol lines, based on more complete data, may show no pools of oil in rocks of higher carbonization than 65 per cent fixed carbon. It will also be noted that the eastward trend of the isovols in the southern Virginia region, on account of fault compensation of the stresses, finds a response in an eastward oil pool trend, which will probably be more clearly shown when the eastern Kentucky region is more fully explored by the drill. Moreover it appears that not only does the eastern border of the oil field swing eastward in Kentucky, but the oils, even those in pre-Carboniferous strata, lying in the strike of the high gravity oil pools to the northeast

are of lower gravity corresponding to the lesser alteration of the coals of the region in eastern Kentucky.

If now, turning to Oklahoma, attention be given to the southeastern border of the mid-continent oil field, it will again be seen that the commercial pools, so far as discovery has gone, appear not to reach the 65 per cent fixed carbon isovol, though the marginal developments parallel this line.

In view of the eastward continuation of the oil-bearing formations, including the oil sands both in the Appalachian region and in Oklahoma and Arkansas, and taking into account their porosity as ascertained from drillings, and the distinctly favorable structures, elevations, etc., of the beds—in short, in view of the absence of any other visible geological reasons why commercial oil pools do not occur in regions of higher carbonization of the residual organic débris—two questions arise. The first is whether oils, in commercial pools, are anywhere found in or beneath formations in which the regional alteration of the coals is marked by fixed carbon percentages of more than 65 or 70. The second question is why the oil stops near this line. As to the first, I can only say that the relations to be observed in other North American oil fields conform to those found in the Appalachian province. Further, that so far as I have had the opportunity to gather the information concerning the oil fields and the coals in other continents, no productive pools are present in such areas of greater alteration.[19] In fact, though the examination of the data is not yet fully completed, it has been carried far enough to make practically certain the conclusion that commercial oil pools have never been found in regions of further reduction of the carbonaceous detrital deposits, and to establish with nearly equal assurance the conclusion that productive oil pools do not exist in those regions.

Assuming, however, that variable intensities of thrust, due perhaps to local structures, have permitted the escape of small isolated areas from the more advanced alteration in regions of higher rank carbonization, it may be more conservative, pro-

[19] Possible exceptions are to be sought in the Katalla field in Alaska and in the provinces of Shansi and Shensi in China.

visionally, to place the ultimate limit at the 70 per cent fixed carbon line in the coals, though it is not probable that many large pools will be found near this limit. As related to the oil field limit, as here defined, mention may be made of the evidence of the transformation and reduction of the lump resins in the Tertiary and Mesozoic coals when these coals reach a stage of about 68 per cent or 70 per cent of fixed carbon, as I have described in another paper.[20] It will also be recalled that in the regions of more advanced alteration, as in the semi-bituminous coal fields (75 per cent or more of fixed carbon), the cannels appear to have lost their characteristic fatty characters and to have become deadened so as to give essentially the same analyses as the associated humic coals. Field examinations indicate that deposits, once cannels, are as numerous in the semi-bituminous and anthracite coal fields as in the average "bituminous" coal field.

According to the conclusions here given as to oil field limits we appear to have at hand a basis on which to exclude large areas of sedimentary strata from the provinces in which we may, with any hope of success, undertake the costly search for oil by the drill. No oil is reasonably to be hoped for in the Paleozoic formations throughout the greater part, at least, of the area of the Arkansas coal field nor for some distance beyond the margin of this field on the sides toward which the fixed carbon is increasing in direction. Similarly, the very low limits placed on the distribution of oil pools by the regional alteration of the hydrocarbon deposits show the hopelessness of any search for oil in commercial quantities in the Carboniferous or older formations of central and southern New England and of the Appalachian region to the east of the 65 or 70 per cent fixed carbon lines in the carbonaceous deposits. This does not preclude the discovery of pools in the overlying Triassic deposits wherever they are not too far altered, nor in the Coastal Plain deposits to the eastward and southward. However, it is probable that any commercial deposits of oil that may be found in

[20] Resins in Paleozoic plants and in coals of high rank, U. S. Geol. Survey, Prof. Paper **85**: 65–96. 1913.

the Atlantic Coastal Plain formations will be of comparatively low rank, and that those of the Tertiary will not be better than 25° or 27° Baumé. On the other hand, in the Paleozoic areas of the southern Allegheny region, oil pools of commercial value may, if other geologic factors are favorable, be expected wherever the fixed carbon of the coals does not exceed 60 per cent in the pure coal, with a less promising possibility of finding pools as far east as the 65 per cent isovol.

The relations between the rank of the oils and commercial oil field limits on the one hand, to the progressive alteration of the organic detrital deposits on the other, appear to be as significant in the Cretaceous and Tertiary formations of western America and Mexico as in the eastern Paleozoic areas.

CONCLUSIONS

The comparison of the gravities of the oils in different formations and regions, with especial reference to the stages of the regional alteration of the mother rocks and other carbonaceous deposits found in the same formations or in formations overlying the oil pools in the various regions, though it is somewhat unsatisfactory on account of the lack of better information as to the chemical characters of the petroleums, leads to the following conclusions:

(1) Petroleum is a product generated in the course of the geodynamic alteration of deposits of organic débris of certain types buried in the sedimentary strata.

(2) The quantity and characters of the oils generated are determined by: (a) the composition of the organic deposit at the beginning of its dynamo-chemical alteration; (b) by the stage in the progress of the dynamo-chemical alteration of the organic substances; (c) by the elimination, under certain conditions, of the heavier and more viscous hydrocarbons through filtration incident to migration. How far each of the above mentioned factors is responsible for the characters of the petroleums remains to be determined by observation and investigation, both in the field and in the laboratory. It is probable

that the composition of the mother organic deposit largely regulates the types of oils. It may account for the nitrogen, sulphur content, color, etc., just as the nature of the ingredient débris controls the types of the coals. On the other hand, we may conclude that, further in parallelism with the residual coal débris, the rank of the oils within each type is mainly governed by the stage in the progressive alteration (really the natural distillation) of the organic deposits.

(3) In general, it is seen that the lowest rank oils of each type are found in the regions and formations in which the carbonaceous deposits are least altered; that the oils in formations showing greater alteration of the organic débris, as in subbituminous coals, are of higher rank, the oils being still more clearly of high rank in the regions and formations of bituminous coals; and that in regions of still further alteration the oils are still better, the highest rank oils being, on the whole, found in regions where the carbonaceous deposits in the same or in overlying formations have been brought to corresponding higher ranks.

(4) The effect of progressive regional dynamic alteration is marked by a concentration of hydrogen in the distillates and a concentration of carbon in the residual débris (coal, carbonaceous shale, etc).

(5) Abnormally light oils, occurring sporadically in pools of lower rank are, in most cases at least, probably due to filtration, though it is not improbable that, in some cases, these oils are migrates from underlying formations of more advanced alteration.

(6) In general, at a given point the oils found in successive underlying formations or in stratigraphically lower sands in the same formation are progressively higher in rank. In other words the principle that the increase in the gravity of the oil is inverse to the stratigraphic depth of the well, proposed by Engler, finds its parallel in the downward increase in the carbonization of coals, according to the law of Hilt.[21] Occurrences of lighter

[21] Oils found so near the outcrop or at such shallow depths as to have permitted the evaporation of the lighter hydrocarbons or the intrusion of oxygen in meteoric water should be regarded with suspicion.

oils in sands overlying others, in the same geologic formation, carrying heavier oils, may, in many cases at least, be due to differences in the mother organic deposits. However, the effects of filtration are not to be overlooked.

(7) In regions where the progressive devolatilization of the organic deposits in any formation has passed a certain point, marked in most provinces by 65 to 70 per cent of fixed carbon (pure coal basis) in the associated or overlying coals, commercial oil pools are not present in that formation nor in any other formations normally underlying it, though commercial gas pools may occur in a border zone of higher carbonization. The approximate carbonization limits of the rocks containing or overlying oil pools may be found to vary somewhat in different provinces according to the characters of the original organic débris, the circumstances attending its deposition and the geologic structure.

(8) Wherever the regional alteration of the carbonaceous residues passes the point marked by 65 per cent or perhaps 70 per cent of fixed carbon in the (pure) coals, the light distillates appear, in general, to be gases at rock temperatures. Occluded oils may, in some cases, have escaped volatilization.

The observations and conclusions here offered suggest a wide range of problems, both scientific and economic, that merit thorough investigation with greater refinement of criteria as well as of methods. A greater volume of detailed analytical data concerning petroleums is needed for comparisons from the geographic and stratigraphic standpoints. Detailed paleontological investigations should be made of the detrital organic deposits laid down under different conditions in marine and fresh waters, and the decomposition products generated in the biochemical process, as well as in the dynamo-chemical process, should be chemically studied in detail.

Some of the features of the regional alteration of coals and petroleums that are here lightly touched upon will be more fully discussed in a more extended paper now in preparation for publication by the U. S. Geological Survey.

ZOOLOGY.—*The bathymetrical and thermal distribution of the unstalked criniods, or comatulids, occurring on the coasts of China and Japan.* AUSTIN H. CLARK, National Museum.[1]

The fauna of the coasts of China and Japan includes 92 recognized species and subspecies of comatulids, of which 2 are probably best considered as local aberrant forms, so that the actual number may be placed at 90.

Of these 90, 61 belong to the Indo-Pacific fauna, characterizing the Southern Japanese division of that fauna, which ranges from Hong Kong and Formosa to the Korean Straits and thence eastward to Tokyo Bay; 22 are Malayan, widè ranging types, each with a distribution different from that of the others; 4 are Antarctic, reaching Japan from the northeastward by way of Alaska and the Aleutian Islands; and 3 (plus varieties of one of them—5 in all) are Arctic. One of these last, *Heliometra glacialis maxima* (with *Heliometra glacialis biarticulata* and *Heliometra glacialis brachymera*) is very closely related to *Heliometra glacialis . glacialis*, which occurs in the Arctic Ocean from west of Greenland to the Kara Sea, and southward to Nova Scotia and northern Norway, but the other two are of quite different origin; *Psathyrometra erythrizon* was originally Antarctic, like *Psathyrometra fragilis*, to which it is closely related, and entered the Seas of Okhotsk and Japan from the northeastward; *Thaumatometra tenuis* is most closely related to species in the

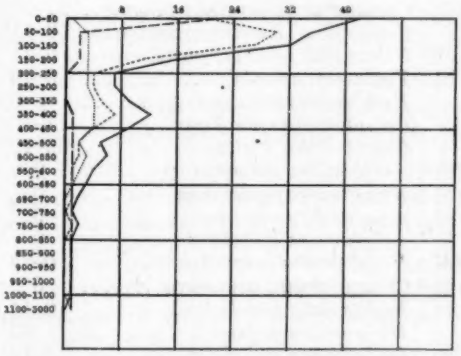

Fig. 1. The frequency at different depths of the comatulids of the coasts of China and Japan. ------ The Species of the Indo-Pacific Fauna; —— —— The Species of the Malayan Fauna; ..... The Species of the Arctic and Antarctic Faunas; ——— The Total for all Species.

[1] Published by the permission of the Secretary of the Smithsonian Institution.

Bathymetric and thermal ranges of the comatulids occurring along the coasts of China and Japan

		Depth in fathoms	Temperature
M	*Comatella stelligera*	0–36	(24+)
	Comatella decora	95–106	13.28
M	*Capillaster macrobrachius*	0	(24+)
	Capillaster mariæ	0–59	16.72
M	*Capillaster multiradiata*	0–160	(24+)
M	*Comatula solaris*	0–14	(24+)
	Comatulides decameros	170	?
M	*Comaster gracilis*	0–30	(24+)
M	*Comaster fruticosus*	19–58	24.28
	Comaster serrata	30–106	13.28
	Comantheria intermedia	83	?
	Comantheria grandicalyx	0	(24+)
	Comantheria imbricata	36–50	?
	Comanthus (Bennettia) solaster	0–108	13.28–18.00
	Comanthus (Bennettia) pinguis	21–125	14.33–15.89
	Comanthus (Bennettia) japonica	0–140	11.28–16.72
M	*Comanthus (Vania) parvicirra*	0–44	(24+)
M	*Zygometra comata*	0–49	(24+)
	Eudiocrinus variegatus	60	?
	Catoptometra rubroflava	14–100	16.72
	Catoptometra hàrtlaubi	63–152	13.33
M	*Amphimetra schlegelii*	0	(24+)
M	*Amphimetra variipinna*	0	(24+)
M	*Amphimetra sinensis*	0	(24+)
M	*Amphimetra lævipinna*	0	(24+)
M	*Himerometra magnipinna*	0–21	(24+)
M	*Craspedometra acuticirra*	0	(24+)
M	*Dichrometra flagellata*	0–14	(24+)
	Dichrometra dofleini	83	(24+)
	Dichrometra döderleini	0–84	23.78
	Mariametra subcarinata	22–59	16.72
	Mariametra delicatissima	84	23.78
	Liparometra grandis	40	?
M	*Lamprometra protectus*	0–12	(24+)
M	*Cenometra bella*	0–20	(24+)
	Cyllometra albopurpurea	12–139	11.61–23.78
	Decametra tigrina	8–34	(24+)
	Prometra owstoni	55	?
	Oligometra japonica	5–8	?
M	*Oligometra serripinna*	0–50	(24+)
	Tropiometra macrodiscus	0–50	?
M	*Tropiometra encrinus*	0	(24+)
	Neometra multicolor	11–333	13.28–15.89
	Gephyrometra versicolor	53	16.50
	Gephyrometra propinqua	95	13.28

		Depth in fathoms	*Temperature*
	Pectinometra flavopurpurea	63–200	8.67–17.22
	Calometra callista	107–139	11.61
	Calometra separata	55–150	13.28–15.89
	Asterometra macropoda	103	15.89
	Asterometra anthus	103	15.89
	Asterometra lepida	35	?
	Cosmiometra aster	369–405	4.44– 5.44
	Cosmiometra conifera	?	?
	Stenometra dorsata	52–170	11.28–15.89
	Daidalometra hana	107–139	11.61
	Parametra alboflava	103	15.89
	Parametra orion	71–170	10.78–15.89
	Thalassometra latipinna	345	5.05
	Thalassometra pubescens	440	5.44
	Pachylometra septentrionalis	?	?
	Glyptometra lata	361	5.95
	Chlorometra garrettiana	95	13.28
	Strotometra hepburniana	100–135	11.28
	Pœcilometra scalaris	361	5.95
	Euantedon sinensis	?	(24+)
	Compsometra serrata	8–35	?
	Iridometra adrestine	13–107	11.61
	Iridometra psyche	30–107	11.61
	Iridometra briseis	59	16.72
	Thysanometra tenelloides	70–197	8.67–13.50
Arc.	*Psathyrometra erythrizon*	390–406	0.39
Ant.	*Psathyrometra fragilis*	300–533	1.61– 2.17
	Perometra diomedeæ	39–139	11.61–20.39
	Erythrometra ruber	55–150	11.11–15.89
Arc.	*Heliometra glacialis maxima*	32–428	−1.22– +1.72
Arc.	*Heliometra glacialis biarticulata*	?	?
Arc.	*Heliometra glacialis brachymera*	[172]	[1.05]
Ant.	*Florometra mariæ*	70–337	4.83–13.50
Ant.	*Florometra rathbuni*	533–587	2.17–383
	Cyclometra clio	107	?
	Nanometra boversi	139–191	9.67–13.33
Arc.	*Thaumatometra tenuis*	80–620	0.39–1.72
	Thaumatometra isis	361	5.95
	Thaumatometra comaster	300–533	1.61– 2.17
	Thaumatometra cypris	775	3.11
	Thaumatometra parva	120–265	?
Ant.	*Bathymetra abyssicola*	2900	1.83
	Thaumatocrinus borealis	361	5.95
	Pentametrocrinus tuberculatus	169–333	8.89
M	*Pentametrocrinus diomedeæ*	103–186	13.33–15.89
	Pentametrocrinus japonicus	139–662	3.17–13.33
M	*Pentametrocrinus varians*	361–1050	3.17– 5.95

The frequency at different depths of the comatulids occurring on the coasts of China and Japan

Fathoms	*All species*	*Indo-Pacific species*	*Malayan species*	*Arctic and Antarctic species.*
0–50.....	42	20	21	1
50–100.....	35	30	2	3
100–150.....	32	27	2	3
150–200.....	16	11	2	3
200–250.....	7	4	0	3
250–300.....	7	4	0	3
300–350.....	9	5	0	4
350–400.....	12	7	1	4
400–450.....	9	4	1	4
450–500.....	5	2	1	2
500–550.....	6	2	1	3
550–600.....	4	1	1	2
600–650.....	3	1	1	1
650–700.....	2	1	1	0
700–750.....	1	0	1	0
750–800.....	2	1	1	0
800–850.....	1	0	1	0
850–900.....	1	0	1	0
900–950.....	1	0	1	0
950–1000.....	1	0	1	0
1000–1100.....	1	0	1	0
1100–3000.....	1	0	0	1

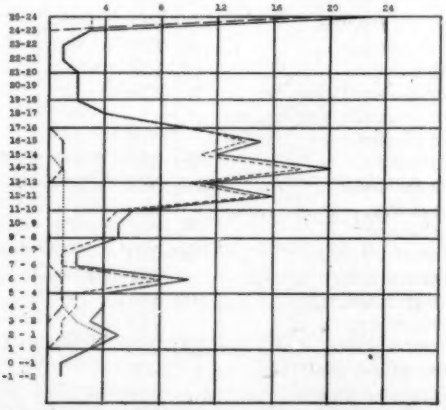

Fig. 2. The frequency at different temperatures of the comatulids of the coasts of China and Japan. ------ The Species of the Indo-Pacific Fauna; —— —— The Species of the Malayan Fauna; ..... The Species of the Arctic and Antarctic Faunas; ——— The Total for all Species.

The frequency at different temperatures of the comatulids occurring on the coasts of China and Japan

Degrees Centigrade	*All species*	*Indo-Pacific species*	*Malayan species*	*Arctic and Antarctic species*
25–24.....	23	3	20	0
24–23.....	3	3	0	0
23–22.....	1	1	0	0
22–21.....	1	1	0	0
21–20.....	2	2	0	0
20–19.....	2	2	0	0
19–18.....	2	2	0	0
18–17.....	4	4	0	0
17–16.....	10	10	0	0
16–15.....	15	14	1	0
15–14.....	12	11	1	0
14–13.....	20	18	1	1
13–12.....	11	10	0	1
12–11.....	16	15	0	1
11–10.....	6	5	0	1
10– 9.....	5	4	0	1
9– 8.....	5	4	0	1
8– 7.....	2	1	0	1
7– 6.....	2	1	0	1
6– 5.....	10	8	1	1
5– 4.....	4	2	1	1
4– 3.....	4	2	1	1
3– 2.....	3	1	0	2
2– 1.....	5	1	0	4
1– 0.....	3	0	0	3
0– −1.....	1	0	0	1
−1– −2.....	1	0	0	1

Southern Japanese division of the Indo-Pacific fauna, and probably reached the Sea of Japan through the Korean Straits.

In the foregoing lists are included all the comatulids known from Chinese and Japanese waters, with their bathymetric and thermal ranges. The fauna to which each belongs is indicated as follows: *M.*, Malayan; *Arc.*, Arctic; *Ant.*, Antarctic; those not especially marked belong to the Southern Japanese division of the Indo-Pacific fauna.

In the diagram (fig. 1) on which are shown the bathymetric ranges of the species of the different faunal units which collectively constitute the comatulid population of the Chinese and

Japanese coasts it is interesting to note that the species of each of these units show the same line that the corresponding species of the same units show in other parts of the world. The mingling of the faunas here, as elsewhere, has resulted in a distinctive collection of individuals which, however, is easily resolved into the original component units, and these component units are found to retain all the distinctive features of the parent faunal groups from which they were originally derived. In their relation to temperature the three faunal groups are very different. The Malayan species, which are mostly confined to the littoral, almost all occur in water with a temperature above 23°, but they are also represented between 12°, and 16°, and 2° and 7°. The Indo-Pacific species have their maximum between 10° and 18°, and especially between 13° and 14°; they are also numerous between 5° and 6°. The Arctic and Antarctic types, which do not occur in water warmer than 15°, are most numerous between 0° and 2°.

We get, therefore, the following optimum temperatures for these three components of the Japanese and Chinese fauna:

Malayan.....	**23+°**	12°–16°	2°–7°
Indo-Pacific.....	23+°	**13°–14°**	5°–6°
Arctic and Antarctic...			**0°–2°**

The point 2° to 7° (including 5° to 6°) is characterized especially by the genera of Oligophreata with highly developed side- and covering-plates along the ambulacra of the pinnules and arms (included in the families Thalassometridæ and Charitometridæ) which, occurring from 0 to 1600 fathoms, are most noticeable between 350 and 400 fathoms; most of these belong to the Indo-Pacific fauna, but a few are Malayan.

Although on the Japanese coast it is possible to take species of the Indo-Pacific and the Antarctic, and of the Indo-Pacific and Malayan, faunal units in one and the same dredge haul, it is evident that this overlapping, which in some places is quite extensive, does not mean that these faunal units here have lost or are losing their identity.

ANTHROPOLOGY.—*Institutional marriage.* J. R. SWANTON, Bureau of Ethnology.

Much of ethnological investigation consists in a study of various manifestations of the conscious and the habitual, and the determination of the relative influence exerted by them on a certain people, a certain feature of their life, or a certain epoch of their history. We have here to deal, however, not with individual consciousness and individual habit, but with collective consciousness and collective habit. A study of the manifestations of these two forces as exhibited in almost every department of primitive life, whether material, esthetic, social, or religious, would be both interesting and instructive. Here it is proposed merely to consider the part they play in the single, albeit important, institution of marriage.

At all periods of the world's history and in all parts of the world known to us man has exhibited a preference for marrying among certain races, classes, or groups, and an aversion against marriage in certain others. Broadly speaking there are two different forms which the aversion takes—aversion towards marriage between persons closely related by blood or supposed to be so, and aversion toward marriage between those of very diverse races, tribes, social status, beliefs, and mentality generally. The origin of the latter is in some measure comprehensible, but the origin of the former not so clear and it has been the subject of considerable discussion. Yet the fact is well known and may, for our present purpose, be assumed. Under both of these aversions it must be remembered that we include, not so much the aversion of certain persons to marry, as the aversion to have them marry on the part of the entire community, the social aversion so to speak.

Aversion to marriage beyond certain limits operated in primitive society to prevent many marriages from taking place outside of the tribe, and at best such marriages were confined within a relatively restricted area. As national units grew larger and means of communication easier this area constantly expanded; it was never larger than it is today, but is still in evidence as applied to certain races, peoples and religious sects.

Where the aversion to close marriages obtains we should expect the exogamous group to consist of the blood relations of each individual, the number of such individuals within the tabooed class being determined either by the intensity of the opposition to intermarriage of blood kin or the ability of the people to trace relationship. Such a condition is found in modern white society, though it is not pressed to the extreme limit. Among the primitive races of North America, to which I shall particularly devote my attention, it is present among the Eskimo of the Arctic shores and islands, among the northern Indians in contact with them, among most of the Athapascan, Salishan, and Shoshonean peoples from the Mackenzie and Yukon rivers on the north to the borders of Mexico, and among most of the tribes of California. Here we may say that exogamy is consciously, and to a certain degree intelligently applied to individuals related by blood. Exceptions may occur in cases of adoption, and no doubt there are other exceptions, but they do not modify the truth of this statement to any appreciable extent.

When we turn to the other portions of North America north of Mexico, however, to the tribes of the North Pacific coast, to the Pueblo Indians of New Mexico and Arizona, to the occupants of the eastern and southeastern woodlands, some of the peoples of the Plains, and one or two in California, we find a very different social condition. There the exogamous group, instead of being determined almost uniformly by blood, is found to be a conventional body which includes persons related by blood and persons not related by blood and excludes persons related by blood and persons not related by blood. Numerous theories have been suggested to account for this apparently anomalous state of affairs, some of which explain it as an institution or condition more primitive than that of the exogamous group founded on blood and would derive the latter from it. One who has carried on investigations among tribes of this class with an unbiased mind, however, can hardly fail to come to the conclusion that the recognition of consanguinity is an original element, and that where an entire class of persons is called by the same term as the true father, mother, uncle, aunt, brother,

sister, son, daughter, nephew, niece, etc., it is rather that the general application is an extension of the particular than the particular a specialization of the general. Such being the case we have to inquire whence came the largest groups over which these terms were extended. Although their origin may have been various there is reason to believe that in the majority of cases these clans or gentes, as we now call them, have originated in geographical groups or bands. At any rate the class of tribes first considered is divided into just such geographical groups, and on the north Pacific coast we find the tribes with clans preserving geographical names for their minor divisions which are in other respects analogous to the clans found elsewhere. On the other hand, in the first class of tribes we find some in which marriage rarely takes place within the band; not because such marriage is prohibited, but because each band being comparatively small, considerably more than half may be recognized as blood relations by most of its members. This condition of affairs is believed to have passed over into a tribal system with clans or gentes through the tendency to marry outside of the band, based on nothing more pronounced than blood relationship, which made clan endogamy successively avoided, looked down upon, tolerated, and finally prohibited. Be that as it may, the terms of relationship originally based on consanguinity came to be associated with social groups or clans which had only incidental connection with blood relationship, and, so identified, its original significance became obscured or lost; it became a conventionalized institution in which was preserved to only a slight degree the consciousness of its origin. This was the same evolution as that gone through by the people in their material culture, arts, and ceremonial life. We will now turn to a consideration of some of the different directions in which it was developed.

In the first place tribes of this class may be divided between those reckoning descent through the father and those reckoning it through the mother. When the group into which marriage is prohibited becomes stereotyped into an artificial body it is evident that the particular body to which each child is to belong

has to be determined in some definite manner. Conceivably he might have rights of membership in two clans at the same time, or he might belong to either in accordance with his own choice, and we do indeed find just this condition among some of the Salish tribes of British Columbia, notably the Lillooet. It is, however, evident that such an arrangement would present certain practical difficulties. In the first place, it would be unstable and likely to disintegrate or to change into something else. Secondly, it would be difficult to preserve a balance between the different groups, and we know that such groups were usually jealous of losses. For this and probably other reasons it came about that in almost all tribes with clans the clanship of the child was determined at birth either into the clan of the father or that of the mother. In the former case a man considered his father's clansmen to all intents and purposes as his family, and in the alternative case he so regarded his mother's clansmen. This meant that marriage could not be contracted by him in the one case into the clan of his father and in the other case into that of his mother. Among some tribes this appears to have been the sole marriage prohibition, but in far more there was also strong opposition to marriage into the clan of the other parent. The opposition was probably stronger in very early times than later; but it is usually present in some form or other, varying all the way from mild disapproval to absolute prohibition. It is one of those indications that avoidance of close marriage was, at root, the main object of the regulations. Now, granted these two regulations in full force, a married man would have peculiar relations to at least three clans, those of his father, his mother and his wife, and in fact we find that in certain tribes three classes of men and women of as many different clans are fathers, uncles, brothers-in-law, aunts, mothers, and sisters-in-law to each married man.

Of course this is on the assumption that there were more than two clans or exogamous groups in the tribe. We have a number of cases, however, in which there were in fact but two such groups, although then we usually call them "phratries" or "moities" instead of "clans." In tribes of this description it

is evident that we have only one possible choice in marriage. Each man or woman must mate in the other half of the tribe, and theoretically all of the men and women of one-half are fathers or mothers, and uncles or aunts, brothers and sisters, and nieces and nephews or children, while those on the other side are after marriage brothers-in-law, sisters-in-law, and the complementary relations in the fathers' and children's generations. Practically, these terms were sometimes more limited because in large tribes the two exogamous groups were subdivided and a man's attitude toward individuals of the minor groups to which his blood or marriage relations belonged was distinguished in some degree from the rest. This was, however, only an occasional modification.

In tribes with three clans one clan would contain fathers, aunts, brothers and sisters, another mothers, uncles, and perhaps cousins, and a third brothers- and sisters-in-law. In other words, as was the case with two-clan tribes, the whole nation would bear some relation to each individual. Another thing to be noticed is that with absolute exogamy enforced, as respected the clans of both father and mother, there would be a regular sequence of clans in each strain of blood. For if the tribe consists of three clans, Wolf, Bear, and Panther and we assume that marriage takes place between a Wolf man and a Panther woman, descent being male the children will all be Wolves. Now, as they cannot marry into either the clan of the father or into that of the mother, they must marry into the Bear. The children of the boys will belong to the Wolf, of course, and when they marry must marry into the Panther. The children of the girls will be Bear, but they also must marry into the Panther. If we follow the male line we shall, indeed, never have any other clan than the Wolf, but the clan of the mother will alternate in every generation from Panther to Bear and back again to Panther. If we follow the female line we shall have a regular change in each generation from Wolf to Bear, and then to Panther and back again to Wolf. If descent is female the result will be just the converse of this but in its practical results will differ none at all.

Tribes with two exogamous divisions are fairly numerous. Among such may be mentioned the Iroquois, the Choctaw and Chickasaw, the Haida, and the Tlingit, and there are traces in other parts of North America. Tribes with three exogamous divisions are rare, but perhaps further investigation would show that the three Delaware totems were of this character.

In still other tribes we have several clans, but it must be remembered that not all of these clans intermarried freely, certain clans being linked together into phratries, and beyond this each tribe with several clans often consisted of several towns in which not all of the exogamous groups were represented. Thus in the case of the Creek Indians it happened that there were probably few towns which contained more than six or eight exogamous groups and of these some were so insignificant or so slimly represented that there were in most cases not more than four or five exogamous divisions of real importance, and it was between these that nine-tenths of the marriages took place. Such being the case it is evident that in any line of descent there would be a frequent repetition of certain exogamous groups, although the far greater number of clan names would tend to obscure the fact.

Now, although we can not know positively it is possible that, if we could plot the succession of exogamous groups, we should have a somewhat regular alternation. If we assume four exogamous divisions represented by the clans Wolf, Panther, Bear, and Deer, descent being in the female line, we would have the husbands of Wolf women drawn successively from the Panther, Bear, and Deer clans, while in the male line we might have the regular sequence Wolf, Panther, Bear and Deer. It is probable that something approximating this may have existed among the tribes with many clans such as the Chippewa and other central Algonquian peoples, the Creeks, the Pueblos, Navaho and Tsimshian; but for lack of careful investigation, we cannot say so with absolute certainty. Still we do know that such a sequence was bound to occur with tribes of three exogamous groups and something near it would happen with four, for it must be for the women's husbands successively Bear or Deer,

in the first generation and a choice of two only out of the four every time afterward. In the case of the men the succession would be to some extent determined along certain lines, though of course there is no necessity that the line should return regularly to the beginning. Nevertheless, absolute regularity would be attained if the repugnance to close marriages should extend one generation back of that of the parents—on the male side in case descent is matrilineal and on the female side in case it is patrilineal. Supposing that this actually took place and that the parents of self are Wolf and Panther, and the father's father or mother's father (as the case may be) is Bear, there would be, under the conditions laid down, but one clan into which self could marry, viz., Deer. Assuming male descent we should then find that the wives of a succession of Wolf men were Deer, Bear, and Panther in order, this order being repeated over and over indefinitely. In the case of a woman we should have Wolf, Deer, Bear, Panther, back to Wolf again. With matrilineal descent we would have the converse.

Limitation of marriage in these cases would be due to the extension of the repugnance toward marriage in related groups, an exceptional distance from the parties concerned, and the inevitable result would be that a man or woman must marry into some particular clan, not because that clan was arbitrarily picked out but because all others happened to contain persons supposed to be too closely connected. Some of the complications we observe in Australian society may be due to this cause, but many must be attributed to the segmentation of two or four original major divisions or the affiliation of groups of four or eight into two major divisions or moities. In any case the direct result is to limit the choice of a prospective bridegroom or bride to a small fraction of an already small tribe. In this way there has grown up an artificial determination of marriage which has become so much a part of the habitual life of the tribe as to appear not merely right but necessary.

As if the limitations brought about in this way were not sufficient we have in many tribes in addition separation into castes. Besides dividing into or combining together several

coördinate groups social complexes resulted in many places in which some were considered superior and some inferior—some, in other words, with peculiar privileges which others did not have. Thus, on the north Pacific coast of America we have several small clans known by the opprobrious term "food steamers," and among the Natchez there was a superior caste and a crowd of commons beneath. The patricians and plebeians of ancient Rome present a classic example. Except among the Natchez, where conditions were peculiar, the almost uniform accompaniment of a caste system was endogamy of the higher castes, resulting in enforced endogamy of the lower castes. And naturally where there were several grades as many degrees of marriage preference tended to develop, until it came about that the range of selection was reduced from this cause alone within very narrow limits. A contributing cause particularly active in societies divided into castes is the desire to hold together, and perpetuate the property as well as the privileges of a certain limited group. Thus, on the north Pacific coast, although group exogamy is strictly enforced, its effects are nullified by the selective inbreeding of two or three clans of the same caste, whereby practically the same bulk of property is kept within the group and so transmitted.

There were of course various other artificial or institutional limitations placed upon marriage, prominent among which may be mentioned those set by religious creed and sect. While these prohibitions and specifications have resulted from conscious determinations at various times, they have become imbedded in the institutional life of the tribe and produce almost instinctive reactions.

The geographical limits set to intermarriage were and still are to a considerable extent unavoidable; and the racial and tribal limits are both unavoidable and, for the present at least, necessary; but the artificial identification of relationship with groups having no natural connection with it, and the further limitation by caste lines reinforced by economic and religious considerations have made marriage an artificial institution in many countries of the civilized as well as the uncivilized world,

and are bound to react injuriously upon their inhabitants. Under such conditions natural sympathy is overridden and the sexes are brought into unions on materialistic or institutional grounds which result in an unstable combination. Secondly, legitimate procreation being impossible as the result of mutual regard it takes place merely to satisfy the purely sensual appetites and is bound to reacth armfully on the parents and to the detriment of the future generations. Finally, law having proscribed as "immoral" natural unions founded on sympathy and having prescribed as moral those founded on convention, the perception of what constitutes true morality is difficult if not impossible of apprehension, with the result that truly normal unions may take place not recognized by society as moral, prostitutions occur sanctified by law and by religion, while in the face of this grotesque failure of society to recognize true values some will throw over all belief in and practise of morality and will form and break off unions to suit their every caprice, thus practically throwing the whole marriage institution overboard. Yet in such cases the first sinner is society itself, in prescribing unions from irrelevant considerations of clan, caste, sect, propinquity, property, and position.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE CHEMICAL SOCIETY

The 244th meeting was held at the Cosmos Club on Thursday, January 21, 1915. The following resolution, presented by the committee, F. W. CLARKE, W. F. HILLEBRAND, and F. P. DEWEY, was adopted:

"ALBERT CHARLES PEALE, geologist and paleobotanist, and since 1898 in charge of the paleobotanical collections of the U. S. National Museum, died in Philadelphia on Saturday, December 5th, in the 65th year of his age. Dr. Peale was one of the original members of the Washington Chemical Society, and was for several years its secretary; for although he was not specifically a chemist, his interest in chemistry was very strong. His one noteworthy contribution to chemistry was Bulletin No. 32 of the United States Geological Survey, published in 1886, entitled "Lists and Analyses of the Mineral Springs of the United States;" a valuable compilation of all the data then accessible to the author, and very useful to chemists. He was also a pioneer in studying the thermal waters of the Yellowstone National Park. For more than forty years Dr. Peale was connected with the scientific service of the United States, and his friends in Washington are very numerous. The Washington Section of the American Chemical Society hereby expresses its appreciation of Dr. Peale as a man and a scholar, and its sincere regret at his loss."

Waiver of jurisdiction, as a local section of the American Chemical Society, was unanimously made in order to provide for the formation of a Virginia section of the Society.

The following papers were read:

C. O. JOHNS, of the Bureau of Chemistry: *Syntheses of methyl- and methylamino-purines.* A resumé of the work, conducted at the Sheffield Laboratory by Johnson in conjunction with Johns and others on the synthesis of pyrimidines and purines, was presented. In more detail an account was given of the synthesis of the alkyl purines by the author after many unsuccessful attempts had been made.

W. S. HUBBARD and W. L. MITCHEL, of the Bureau of Chemistry, (presented by Mr. HUBBARD): *The hydrolysis of sugar solutions under pressure.* The title might better be the hydrolysis of sugar solutions at elevated temperatures, but to the manufacturer the present title better conveys the idea of the process used. That bacteria, enzymes, acids, salts, elevated temperatures, and pressures under certain conditions bring about hydrolysis is quite well known. In this work high

temperatures were obtained by steam under pressure and the hydrolysis occurred without caramelization. It is necessary to choose the sugar and water with considerable care. A temperature of 124°C., corresponding to a pressure of 1.375 kg. above atmospheric, was found to give the best results under the conditions of the experiment. (Author's abstract.)

Discussion. PHELPS pointed out the possibility that the change in the rate of hydrolysis might be due to the change in H ion concentration. HUDSON spoke of CO_2 under pressure as an agent for the inversion of sugar and the fact that it is generally regarded as a strictly mechanical effect. JOHNSTON pointed out that the effect of pressure alone on reacting solid or liquid systems is greatly overestimated, the temperature and concentration being the important factors. According to PHELPS, in these experiments, pressure increase alone had no effect on the rate of hydrolysis. HUDSON spoke of the work of SPRING as showing the effect of pressure on heterogeneous systems containing no gas phases. JOHNSTON said that SPRING's evidence was very poor and that the strictly pressure effects were very small in cases of true equilibria.

H. C. GORE, of the Bureau of Chemistry: *The concentration of apple juice by freezing.* By freezing, centrifuging to remove the ice and filtering through infusorial earth, apple cider was concentrated to 50 per cent total solids at a cost of 20 cents per gallon of concentrated juice. This juice can be kept without adding preservative. Other fruit juices have been concentrated in the same way.

Discussion: HUDSON inquired whether the juice was filtered before or after concentration. Speaker stated that the filtration could be carried on as easily after as before and was generally done in that way. BERG inquired as to the use of centrifugal filters. Speaker stated that these were found lacking because no suitable clarifier had been found while infusorial earth was entirely satisfactory.

The 245th meeting was held at the Cosmos Club on Thursday, February 11, 1915. Dr. JOHNSTON on behalf of the committee on communications briefly announced a new policy in regard to the programs for the meetings. The aim being to make the programs of wider scope in their interest, the main material is to be furnished on invitation from the committee. In addition it is proposed to have short informal communications, each limited to five minutes. As far as possible it is desired that these informal communications have some bearing on the general topic under discussion.

Carrying out the above policy the following papers were presented: F. E. WRIGHT, of the Geophysical Laboratory: *The petrographic microscope in analysis.* Attention was directed to the fundamental difference between a petrographic microscope and an ordinary microscope. The latter is essentially a magnifier and serves to render visible minute objects and details which are then recognized by their shape, size, and color. In the case of bacteria the differences in behavior with

respect to certain stains aid in the diagnosis, while in other lines of investigation micro-chemical reactions serve the same purpose. The petrographic microscope, on the other hand, is not only a magnifier but also, and essentially, a measuring instrument of precision for ascertaining the optical properties of minute crystal fragments and grains a few hundredths, or even thousandths, of a millimeter in diameter. After a description of the petrographic microscope, considerable stress was placed on the fact that chemists had used, only to a very slight degree, the quantitative aspects of crystals as a means of identification. The various optical properties of crystals that offer possibilities in this direction (refractive index, birefringence, optic axial angle, extinction angle, etc.), and their quantitative determination were briefly described. The potential value of refractive index determinations for identification of either pure substances as such or in crystalline mixtures seems to be little realized among chemists. The method is applicable to quantities (a few hundredths of a milligram) much smaller than can ordinarily be subjected to chemical analysis and the time required is hardly appreciable in comparison. Such measurements of the optical properties of minute crystal grains have been used with great profit at the Geophysical Laboratory in the identification of phases in crystal mixtures and in the study of crystal growth. Of the possible lines of application of petrographic microscope methods in the field of chemical research some of the more important are: The identification and testing of drugs, of poisons, of dyes, of chemical reagents in crystal form, of chemical precipitates, baking powders, sugars and candies, spices, cements, abrasives; in short, of any solid material whether in powder form or in larger masses, crystalline or amorphous. For homogeneity and purity tests the preparation is immersed in a liquid of the refractive index of the main crystal substance which then practically disappears and any foreign material (adulteration or impurity) can be detected at a glance. Methods are also available for estimating the relative amounts of the different substances present in an aggregate. The presentation was accompanied by interesting lantern projections showing the appearance and behavior of minute crystals under the microscope.

Discussion: Many members of the Society took part in the discussion, arising in connection with inquiries as to the application of the methods in certain fields. Such methods have been in use in the study of soils; and the multiplicity of places, in the work of the chemist, where they might be applicable, was soon apparent. Special emphasis was put upon their use in drug identification and in the study and synthesis of organic substances. It was brought out that the practical applicability and importance of the methods will be greatly enhanced when investigators have determined the optical properties of the large number of substances that must be considered in their use in the different branches of chemistry and chemical technology.

L. H. Adams, of the Geophysical Laboratory: *Application of the interferometer to the quantitative analysis of solutions.* The principles of working and use of the Zeiss portable interferometer for liquids were

described. The instrument has been found useful in the analysis of aqueous solutions and is applicable to a large number of liquid binary systems. The sensitiveness in terms of refractive index is about 2 in the seventh decimal place, and therefore salt solutions, for example, may be analysed with an accuracy of 0.0002 per cent. The possibility of error resulting from the wandering of the achromatic fringe was discussed together with methods for the avoidance of this difficulty. Several possible fields of use for the instrument were mentioned.

Discussion: It was brought out in the discussion that the temperature effects, in the comparison of liquids of different concentrations at different times as in the determination of the fixed points of a series of solutions, were not important, since the temperature coefficients of refractive index of the solutions of about the same concentration were nearly identical. The applicability of the instrument to the analysis of alcohol-water mixtures was mentioned, in answer to an inquiry, as being somewhat limited by the solubility of the cement used in making the glass cell container and the difficulties in making up and maintaining known solutions.

An informal communication was presented by E. G. WHERRY of the National Museum on *The detection of certain elements by their absorption spectra.* The spectra of the light reflected from minerals and gems of certain kinds have been found of considerable importance in the identification of these materials. Some 13 or 14 of the elements in their compounds are capable of identification in this way. Most of these belong to what are generally regarded as the rarer elements. The methods developed, in which only the visible spectrum was used, were described. The possible application to the detection of certain elements in other materials was mentioned.

Discussion: The use of the invisible part of the spectrum so as to give the method a greater range of applicability was suggested.

E. C. MCKELVY, *Secretary.*

THE BOTANICAL SOCIETY OF WASHINGTON

The 102d regular meeting of the Botanical Society of Washington was held in the Assembly Hall of the Cosmos Club at 8 p.m., Tuesday, February 2, 1915. Fifty-two members and six guests were present. Messrs. P. A. YODER, STEPHEN ANTHONY, and JAMES M. SHULL were elected to membership. The following scientific program was presented:

S. C. STUNTZ: *Bamboo possibilities in America.* After a brief introductory statement outlining the past history of bamboo introduction into the United States, and sketching the present condition of bamboo planting in this country, attention was directed to the possible future uses for bamboo. Furniture, basketry, especially for parcel post shipments, Venetian blinds, and barrel hoops were suggested as probable industries in which bamboo would find use, while the development for ornamental planting, and as a possible stock for paper was especially emphasized. Lantern slides of bamboo plantations and uses abroad

and in the United States were shown, together with a considerable exhibit of manufactured bamboo articles.

O. F. Cook: *Botany of cacao and patashte.* The patashte tree is a relative of the cacao, known to botanists under the name *Theobroma bicolor* Humboldt and Bonpland. It has dimorphic branches like cacao, the lateral branches being formed in whorls at the ends of the upright shoots, but only 3 laterals in a whorl, instead of 5 or 6, as in cacao. Many other differences in leaves, inflorescences and flowers were shown. The inflorescences of patashte are confined to new growth at the ends of the lateral branches, while cacao is caulocarpous, with all of the flowers produced from the old wood on the trunk and larger limbs of the tree. The various features were explained with lantern-slide illustrations, and the paper was followed by a brief discussion of the question whether trees with such numerous and definite differences should be classified in the same genus.

W. E. Safford: *Rediscovery of Lignum nephriticum.* Lignum nephriticum is a remarkable Mexican wood which was celebrated throughout Europe in the 16th, 17th, and the early part of the 18th centuries, not only for its reputed medicinal properties, but on account of the wonderful fluorescence of its infusion in spring water. Scarcely a fragment of this wood is now to be found in drug collections, and its very name has disappeared from encyclopedias. It is celebrated as the substance with which the Hon. Robert Boyle made his first investigations in the phenomenon of fluorescence. After giving a history of the literature on the subject Mr. Safford called attention to the confusion surrounding the origin of the wood, and the causes which prevented its botanical identification. For the first time specimens of the wood accompanied by herbarium material of the plant from which it was obtained have been the subject of critical study. The heartwood produced the characteristic fluorescence described by Robert Boyle, and the botanical material corresponded with Hernandez' original description of the plant yielding lignum nephriticum. This proves to be **Eysenhardtia polystachya** (Ortega) Safford (*Viborquia polystachya* Ortega, *Eysenhardtia amorphoides* H. B. K.). The lecture was illustrated by lantern slides, specimens of the wood and botanical material, photographic enlargments of sections of the wood made by Dr. Albert Mann, plant morphologist; and also by exhibition of the fluorescence of the extract of the wood in the rays of an arc light by Dr. Lyman J. Briggs, physicist, Bureau of Plant Industry, with remarks as to the value of lignum nephriticum as an indicator in titrimetric determinations. (Author's abstract.)

Perley Spaulding, *Corresponding Secretary.*

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